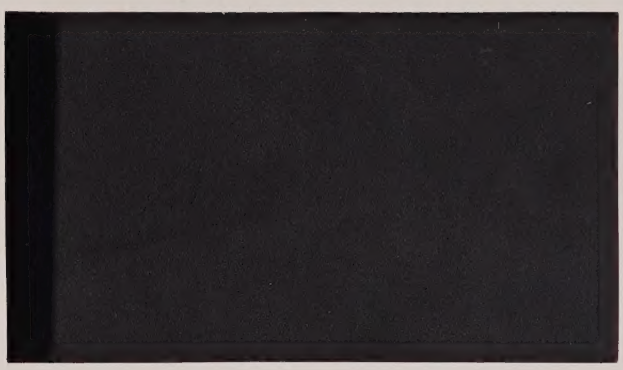
BARBER COLMAN

INSTRUCTION MANUAL

MP MASTER
MA32128

BARBER-COLMAN COMPANY
Industrial Instrument Div. • Rockford, Ill., U.S.A.



1211.9
IN 3-1

MODEL 359A

DIGISET

NULL BALANCE CONTROLLER

INTRODUCTION

This instruction manual is designed to help you secure maximum benefits from your new Model 359A Digiset. It should be given to persons responsible for installation and maintenance of this instrument.

Your Barber-Colman factory trained field engineer is always available for further help in the solution of your control problems. Offices are located in all principal cities.

BARBER-COLMAN COMPANY
Industrial Instruments Division

Litho in U.S.A.

F-12604-1 March 1965

MODEL 359A INSTRUCTION MANUAL

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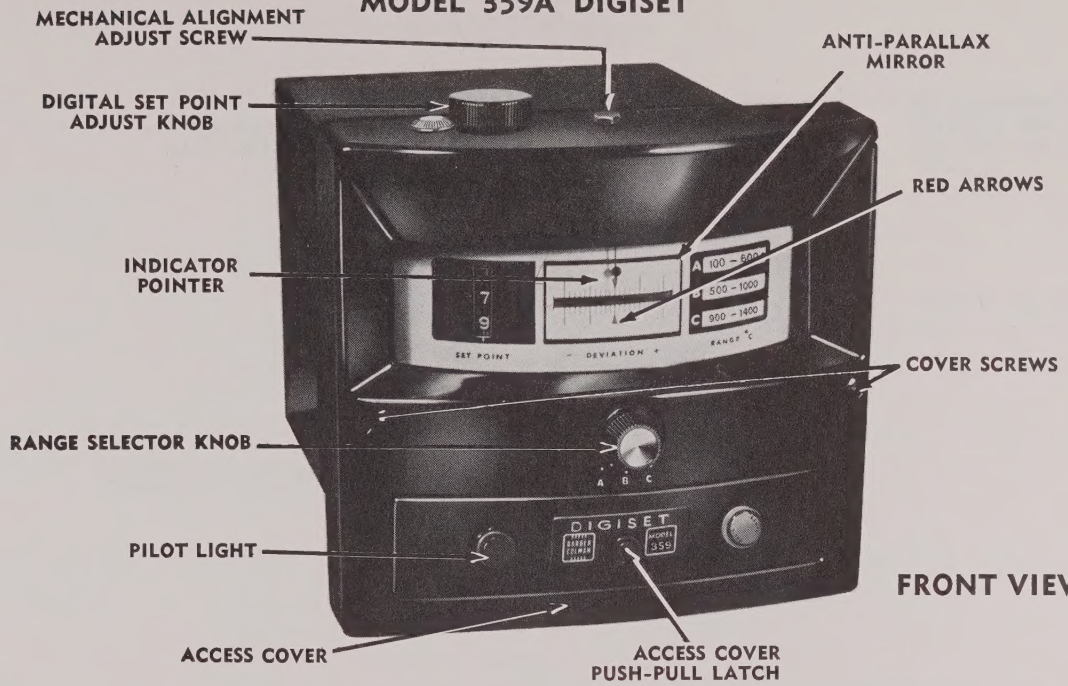
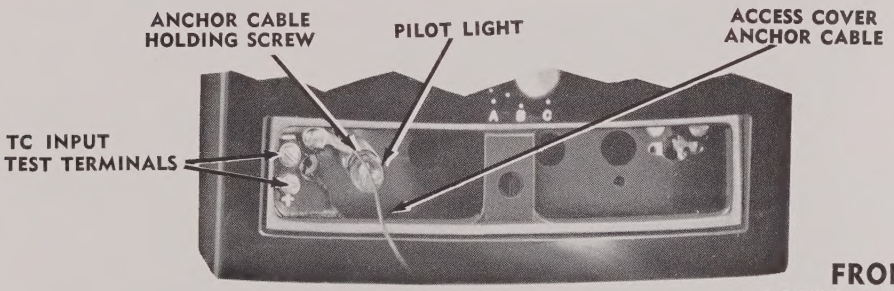
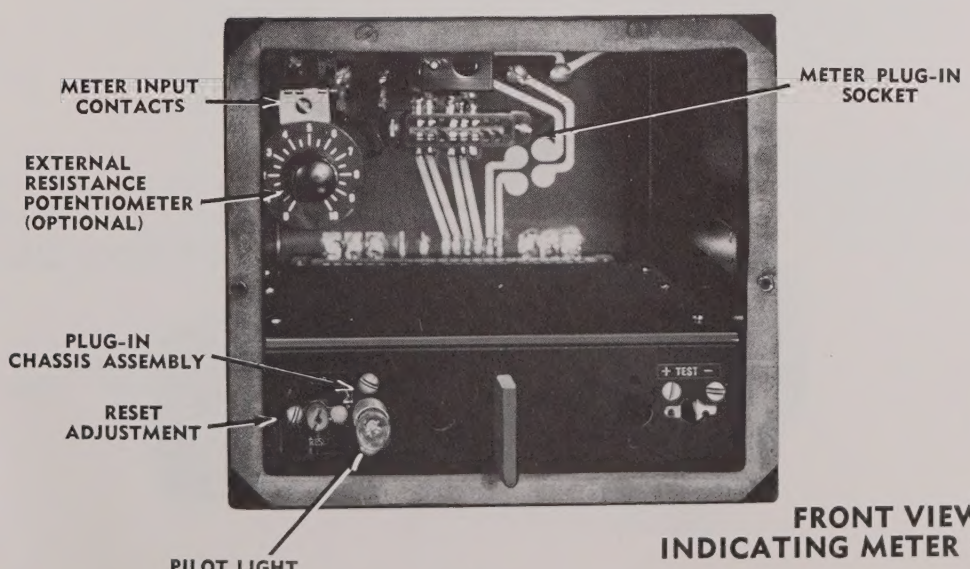
MODEL 359A DIGISET



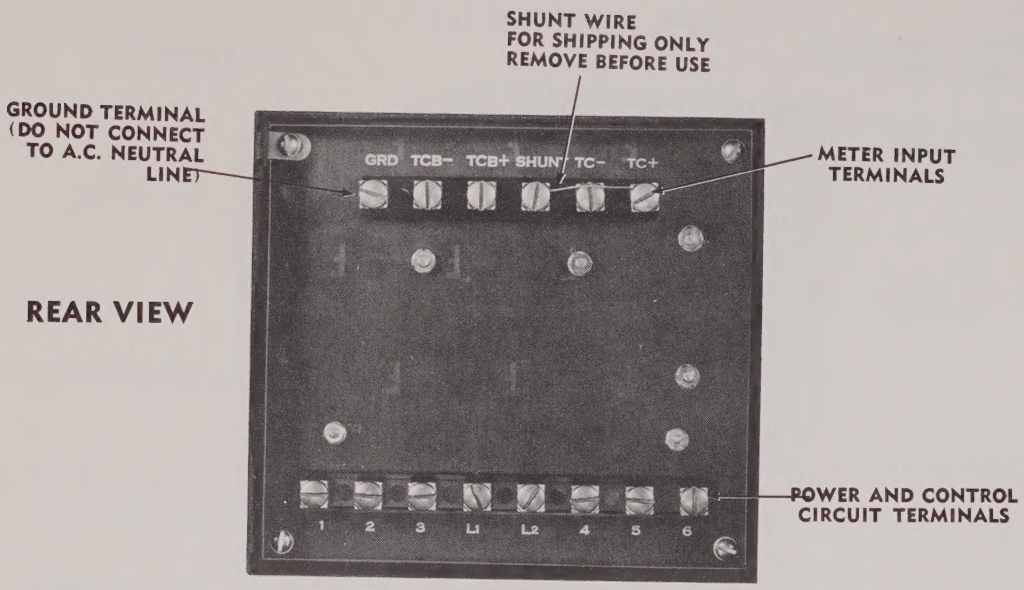
FRONT VIEW

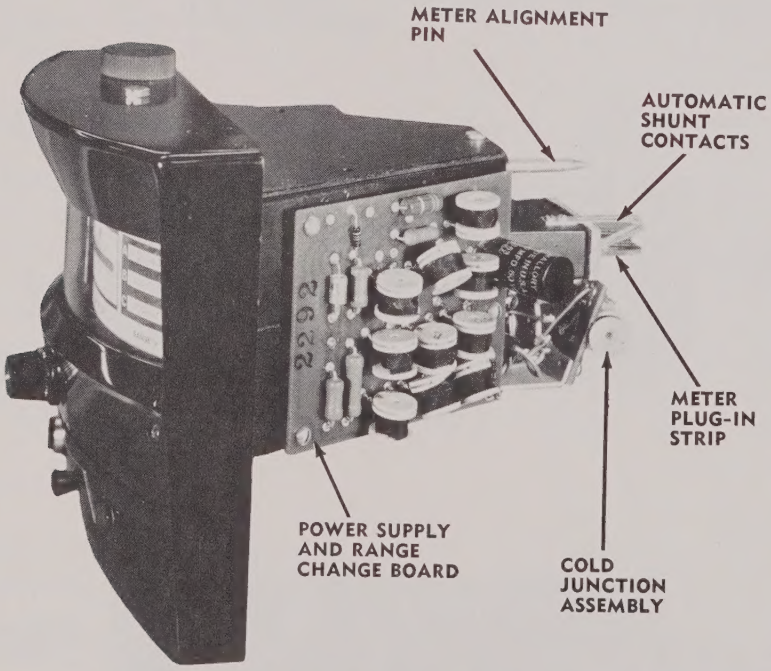


FRONT VIEW
ACCESS COVER REMOVED

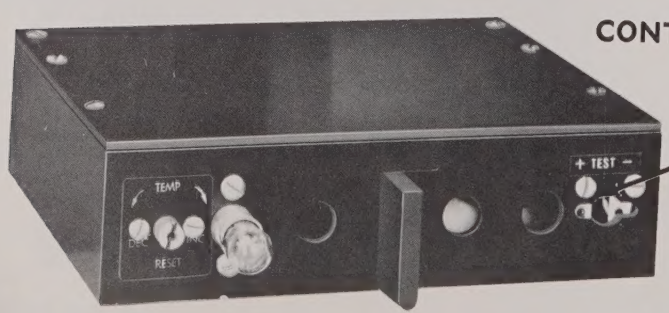


FRONT VIEW
INDICATING METER REMOVED





INDICATING METER ASSEMBLY



CONTROL CHASSIS

OUTPUT
TEST TERMINALS

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DEFINITION OF TERMS

CONTROL SET POINT	The position on the instrument scale to which the control point setting mechanism is set.
CONTROLLED VARIABLE	That quantity or condition which is varied by the controller so as to affect the power of the measured variable. Example: Power to an electric furnace.
CYCLING	A periodic change of the measured variable from one value to another. Oscillation and hunting are synonymous terms.
FINAL CONTROL ELEMENT	That portion of a control system which directly changes the value of the controlled variable. Example: Model 621A Power Controller.
MEASURED VARIABLE	That quantity or condition which is measured and regulated through control of the controlled variable. Example: Temperature in a furnace.
OFFSET	A sustained deviation from control point due to proportional control action. It is the difference existing at any time between control point and the actual value of the measured variable. Droop is a synonymous term.
OSCILLATION	See Cycling.
PROPORTIONAL BAND	That change in value of the measured variable that is necessary to cause full travel of the final control element. It is measured as a percent of full scale span. Throttling range is a synonymous term.
PROPORTIONAL CONTROL	Controller action in which there is a continuous linear relation between the value of the measured variable and the position of the final control element. In other words, the output of the controller is proportional to its input. Synonymous terms are throttling or modulating action.
RESPONSE TIME	The time for the meter indicator to reach 63.2% of the final value after a step change input.
CRITICAL DAMPING	That condition of damping in which the meter movement reaches the point of equilibrium in the least possible time without overshoot.

SPECIFICATIONS

Meter Assembly

a. Meter

Scale Length	30 millimeters or 30 divisions; 1 div. = 1 mm
Sensitivity	0.44 microamps per division (nominal)
Internal Coil Resistance	95 ohms (nominal)
Critical Damping Resistance	275 ohms (nominal) added by using potentiometer in the TC measuring circuit (potentiometer supplied for use with base metal thermocouples only -- optional
Response Time (63.2%)	
w/o damping resistance	5.5 seconds (nominal)
Critically damped	1.4 seconds (nominal)

b. Reference Voltage Source (R.V.S.)

Output Resistance	50 ohms (nominal)
Ranges	See table at back of manual
Line Voltage Stability	± 10% line change results in R.V.S. output change of 3 microvolts or less
External Cold Junction Compensation	Incorporated on all temperature ranges and some millivolt ranges
Adjustable Output	Ten turn linear precision potentiometer with dial lock
Calibrated Accuracy	One-half percent of full scale value. Reading accuracy also depends on thermocouple linearity and tolerance. See page 29.

Control Chassis

Control Output	Proportional d-c voltage
Control Output Span	1 to 11 volts
Proportional Band	Fixed at 17% of scale length (17% = 5.1 div.)
Control Adjustment	Reset internally adjustable to correct for offset
Power Supply	120-130 volt a-c, 50/60 cycle
Power Requirements	9 va

Dimensions and Weights

Overall Dimensions	6 7/8" wide x 6 1/4" high x 9 5/8" deep
Cutout for Flush Mounting	6 1/8" wide x 5 9/16" high. Meter will extend 7 1/4" into panel when flush mounted
Weights	Net - approximately 10 pounds Shipping - approximately 15 pounds

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DESCRIPTION

General Description and Application

The Digiset is a millivoltmeter type null balance indicating controller with a proportional voltage output to drive an MM Series Three-Function Controller. Incorporated in the instrument is a reference voltage source which has a digital setpoint to obtain the desired operating temperature or millivoltage setting. The reference voltage source output is connected in series with the measuring thermocouple so the potential difference between the reference voltage and the thermocouple determines the indicator deflection from the null balance point and therefore the d-c output of the controller. The Model 359A, in combination with the MM Series, is used for controlling magnetic amplifier/reactor systems or silicon controlled rectifier power controllers for the proportional control of load power with rate and reset functions added. The unit uses solid state devices and, when specified, electrical cold junction compensation associated with the desired thermocouple. Other features of the instrument include one percent setability of control set point, multiple range selection and a potentiometer* to adjust the thermocouple measuring circuit resistance for controlling sensitivity and damping of the meter indicator. Operating on the null balance principle, the effect of thermocouple extension wire length is negligible. The instrument has been designed to meet the demand for an accurate and dependable instrument of small size.

Control Specifications

As stated above, the Model 359A, in combination with an MM Series Controller, is used for three-function control of magnetic amplifiers or silicon controlled rectifier power controllers. Magnetic amplifiers are generally used to control saturable core reactors, which in turn regulate the load power. The output range of the Model 359A is 1 to 11 volts d-c as required by the MM Series. The proportional band is fixed at 17% of graduated scale length. The control point is set so that when the meter indicator coincides with the red arrows in the center of the scale, the output of the instrument is approximately 6 volts. Any variation can be compensated for by a reset adjustment to provide the 6 volts needed for proper balancing of the MM Series Controller.

The red signal light indicates that power is applied to the chassis. The output terminals are terminals 5 and 6, with terminal 5 of negative polarity and terminal 6 positive.

*For base metal thermocouples only.

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Electronic Circuit

The Model 359A incorporates a transistorized oscillator and a d-c amplifier. At a position to the left of the red arrows, the collector current of the oscillator transistor is of sufficient magnitude so that the output of the d-c amplifier is greater than 11 volts. As the indicator approaches the red arrows, a small vane or flag suspended from the indicating pointer passes between two flat coils, reducing the collector current of the oscillator transistor. With the flag fully between the coils, the collector current is decreased to a minimum so that the output of the d-c amplifier is 1 volt or less. Proportional control action occurs when the flag traverses a fixed distance between the coils. The position of the flag within the coils, therefore, determines the collector current which then proportionately controls the amplifier output. The proportional band is determined by the level of feedback from the d-c amplifier to the oscillator, regulating the oscillator collector current change with respect to flag movement. In the Model 359A, the proportional band is fixed at 17% of the scale length, but can be made effectively larger or smaller by the proportional band adjustment on the MM Series.

Reference Voltage Source

The reference voltage source consists of a Zener regulated input to a bridge configuration which is designed to minimize the effects of line voltage changes and ambient temperature changes. The regulated output of the bridge supplies a calibrated voltage to oppose the thermocouple input and also energizes the electrical cold junction compensation network. Depending upon customer requirements, up to three adjustable output ranges are available. A ten turn linear precision potentiometer is used with the range selected to obtain the desired control set point value. A dial lock is also supplied so the setting of the unit remains fixed. The digital indication is from 0 to 999. Temperature or millivoltage can be determined by dividing the range span by 1000, giving the number of degrees or millivolts per digit. Ranges available are printed on the right side of the meter scale, with the range selector knob located just below the meter scale. The digital indication is shown on the left-hand side of the meter scale.

The output of the reference voltage source is linear. When calibrated for temperature degrees for a particular thermocouple calibration, the dial reading is not absolutely exact because thermocouples do not have linear potential output with respect to temperature. However, when small temperature spans are utilized the error is diminished. The Model 359A is calibrated so as to give an output approximating the curve and intersecting the curve at two or more points. See Figure 1. In the example shown (0-800°F range using Plat./Plat. 13% Rho.) the midrange of the thermocouple EMF is + 1.794 mv. This is equivalent to 458°F. With a linear millivoltage output of the instrument, tracking line B as shown on the graph, this amount of millivoltage will read out as 429°F. Thus the

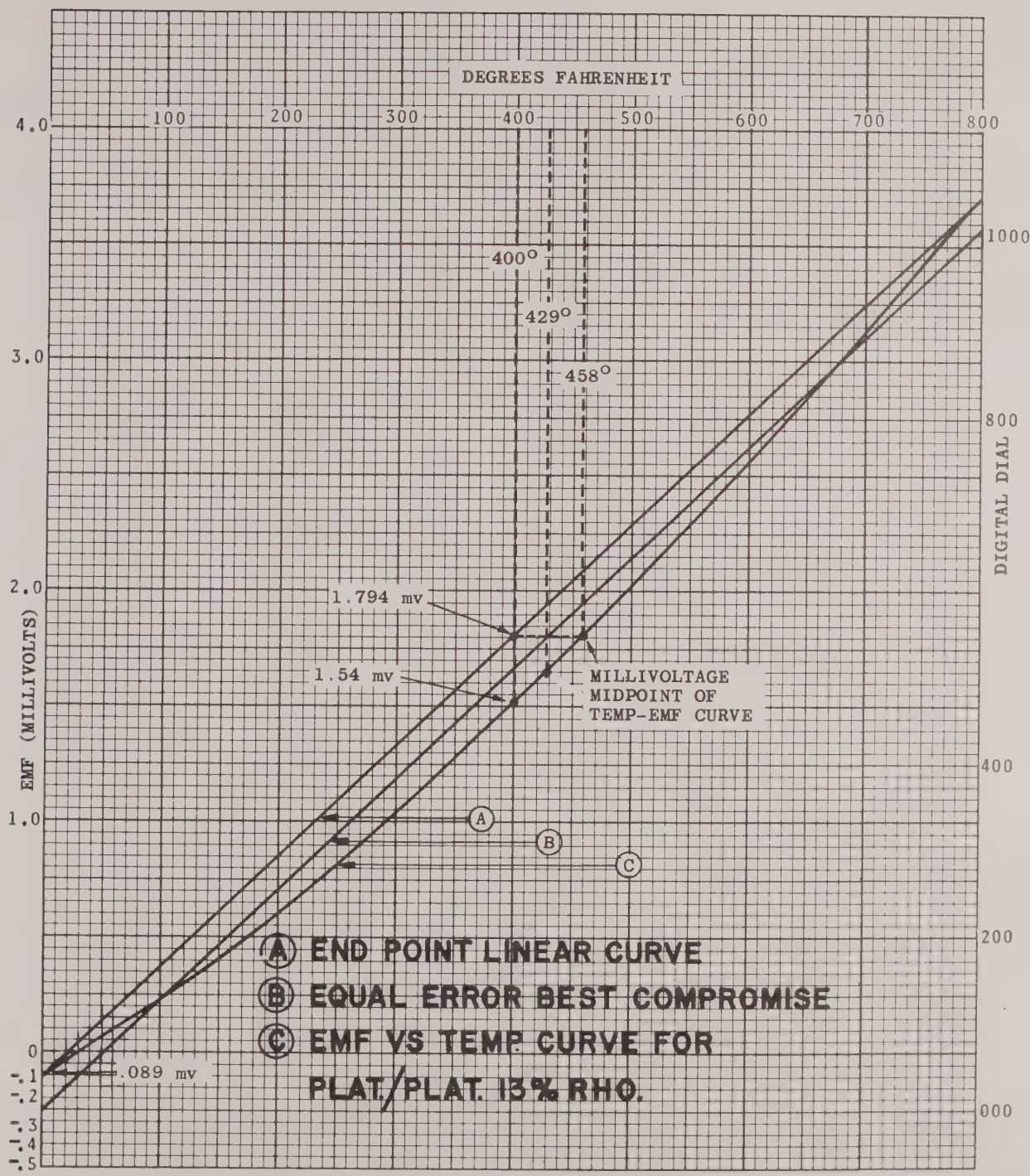

DEGREES FAHRENHEIT
100
200
300
400
500
600
700
800
4.0
3.0
2.0
1.0
0
.1
.2
.3
.4
.5
EMF (MILLIVOLTS)
1000
800
400
200
000
DIGITAL DIAL
400°
429°
458°
1.794 mv
1.54 mv
.089 mv
MILLIVOLTAGE
MIDPOINT OF
TEMP-EMF CURVE
A
B
C
Ⓐ END POINT LINEAR CURVE
Ⓑ EQUAL ERROR BEST COMPROMISE
Ⓒ EMF VS TEMP CURVE FOR
PLAT/PLAT. 13% RHO.

Fig. 1

instrument is in error by 29°F, on the low side, at the midpoint of the range. It can be seen that as the cross-over points are approached the error becomes less, eventually reaching zero, but at either extreme end of the range the error is again maximum although of opposite sign.

NOTE: The 0-800 Plat./Plat.13%Rho. example is an extreme case and is only intended to illustrate the TC non-linearity and linear calibration method. This example also illustrates that 800° cannot be reached with this calibration and range. Ranges should be specified to cover temperatures required. Refer to range tables for actual recommended ranges.

Instruments calibrated in millivolts, with cold junction temperature compensation, are preferred for many applications since problems of thermocouple non-linearities are not encountered. The only inaccuracies present would be those due to production tolerances or thermocouple limits of error. However, when using an instrument calibrated in millivolts, it is necessary to refer to a thermocouple-millivoltage table to determine the millivolts required for the desired temperature. Ask for a "Conversion Data Handbook", form F-10341, from your Barber-Colman sales engineer.

The list of Model 359A standard ranges at the back of this manual also shows the thermocouple non-linearity error for each temperature range and calibration.

Proportional Control

Within the proportional band, the Model 359A will supply a d-c voltage output to an MM Series three-function controller proportional to temperature deviation. The MM Series Controller can be set to add rate and reset functions to the proportional signal. It then provides a d-c milliampere output to an intermediate or final controller. A means of close tolerance control of load power, with minimum overshoot and undershoot, is therefore obtained.

The proportional band of the Model 359A and the MM Controller are inter-related. The adjustment for proportional band (PB) width, as a percent of the Model 359A scale length, is located on the MM unit.

Figure 2 illustrates the percent output of the Model MMC (three-function controller -- current type) for three different proportional band settings. The illustration assumes that rate and reset on the MMC is set at zero. For a proportional band setting on the MMC of 20% the output of the Model 359A is directly related to the output of the MMC. As can be

seen in Figure 2, 10 volts output of the 359A equals 90% MMC output; 6 volts equal 50%, and so forth. For a proportional band spread of less than 20% a lesser voltage of the 359A is required to produce a particular MMC percent output. The voltage output of the 359A will always follow the 17% full scale curve (which is the same as the MMC 20% PB curve), while the MMC output will respond to the percent proportional band setting of the MMC. In the illustration showing a PB setting of 10% of the MMC, a voltmeter attached to the 359A test jacks would read 8 volts with the MMC output at 89%. It can also be seen that the full width of the 359A proportional band is not fully utilized. In this example the MMC output is from 0 to 100% which utilizes only 8.5% of full scale or half the fixed 359A proportional band width.

If the PB setting is greater than 20%, the 359A proportional band is fully utilized, but with a reduction in output span of the MMC. For example, with a 40% PB setting on the MMC the output of the MMC is from 75% to 25% with a corresponding 11 to 1 volt output of the Model 359A. This output change takes place, however, over the fixed 359A proportional band of 17% of full scale. Thus it can be said that the effective proportional band of the system is a function of the proportional bands of both the Model 359A and the MMC (see calculations below), although the actual control range cannot exceed 17% of the 359A scale length. When the indicator is far to the left of the red arrows the output of the 359A is actually somewhat greater than 11 volts, resulting in the output being slightly higher than illustrated.

The effective PB as a percent of scale length can be determined as follows:

$$\% \text{ of scale length} = \frac{17\% \text{ of scale length} \times \text{MM Series PB setting in } \%}{20\%}$$

For example, the effective proportional band width of a Model 359A with a PB setting of 10% on the MM Series would equal:

$$\frac{17\% \times 10\%}{20\%} \quad \text{or } 8.5\% \text{ of scale length}$$

To obtain the number of degrees (°F or °C) represented in the effective proportional band, the two examples discussed in the section entitled "Thermocouple Circuit Resistance" are utilized. Calculations are as per the formula:

$$\text{Degrees/division} \times \text{Effective PB\%} \times \text{Divisions/scale length} = \text{PB width in degrees}$$

For a Model 359A proportional band of 17% of scale length and a 20% setting of the MM unit, the proportional band in degrees Centigrade would be: (see page 18 for determination of degrees/division).

Meter plus R.V.S. Resistance (not critically damped)

4.75°C x 17% of scale length x 30 div/scale length = 24.2°C

This means that a 24.2°C change in temperature will change the control output of the Model 359A from 11 to 1 volts in the proportional band operating range.

For a 10% proportional band setting of the MM:

4.75°C x 8.5% of scale length x 30 div/scale length = 12.1°C

For a 40% proportional band setting of the MM:

4.75°C x 34% of scale length x 30 div/scale length = 48.4°C*

Meter Coil (critically damped)

For a 20% proportional band setting of the MM:

13.5°C x 17% x 30 = 68.8°C

For a 10% proportional band setting of the MM:

13.5°C x 8.5% x 30 = 34.4°C

For a 40% proportional band setting of the MM:

13.5°C x 34% x 30 = 137.7°C*

*This would be the temperature change required if it were possible for the MM output to change from 0 to 100%. See Figure 2.

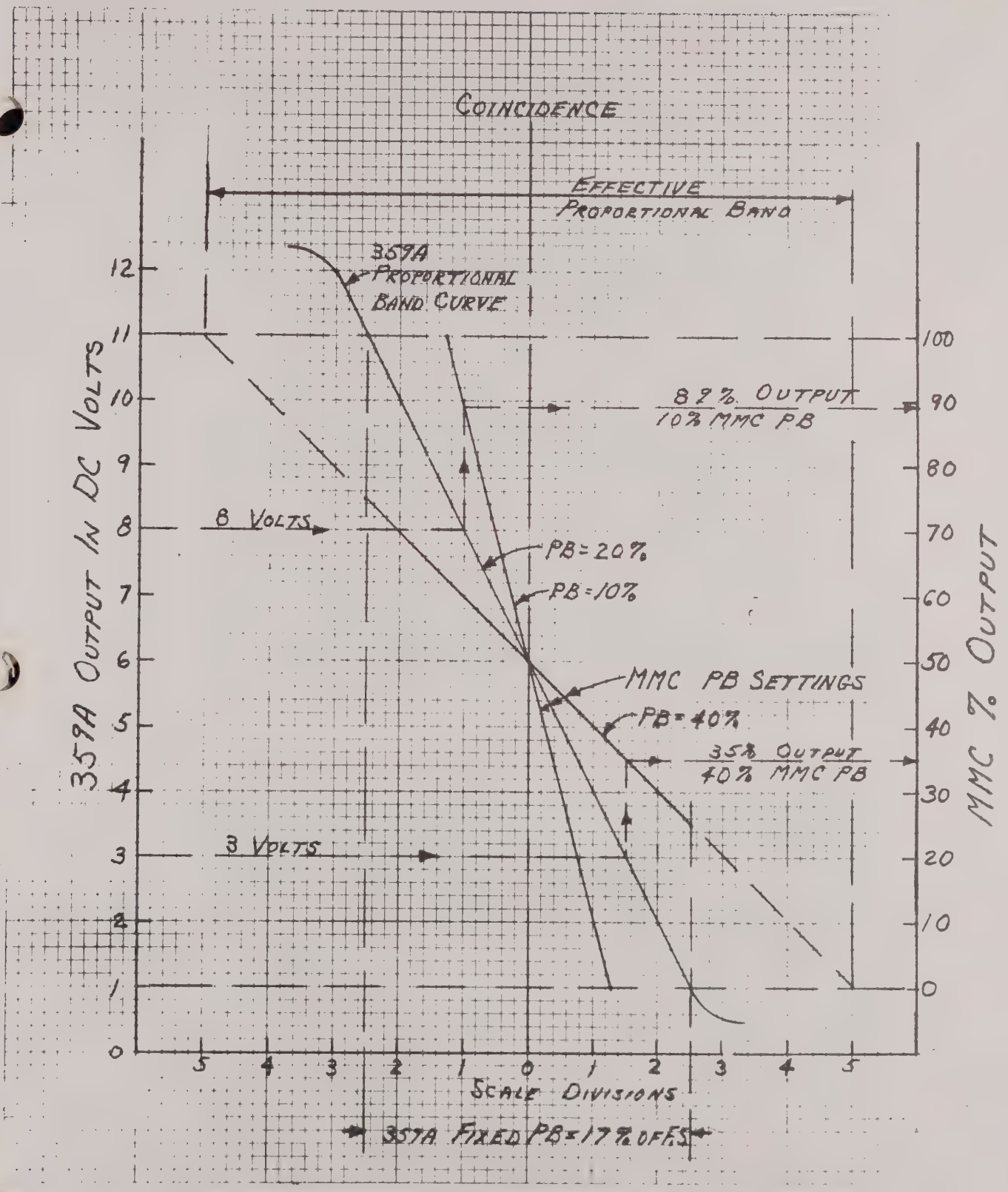

COINCIDENCE
EFFECTIVE PROPORTIONAL BAND
357A PROPORTIONAL BAND CURVE
8 VOLTS
3 VOLTS
PB=20%
PB=10%
MMC PB SETTINGS
PB=40%
82% OUTPUT 10% MMC PB
35% OUTPUT 40% MMC PB
357A OUTPUT IN DC VOLTS
MMC % OUTPUT
SCALE DIVISIONS
357A FIXED PB=17% OF F.S.

Figure 2

Unpacking the Instrument

This precision instrument and its associated equipment have been carefully manufactured and packed at the factory. Remove the instrument and accessories from the packing box and check items against the packing slip. If the equipment is found to be damaged in transit, report damages to the carrier immediately. Repack in original packing box until ready for installation.

CAUTION:

Handle with care.
Safeguard instrument from shock before and after installation.
Avoid oil accumulation and exposure to moisture.
Keep instrument temperature under 130°F and over 40°F.

Mounting Instructions

Locate instrument to avoid excessive vibration, shock, and temperatures outside the range of 40°F and 130°F. Avoid furnace walls, radiation of heat, machine frames, and outside walls. Provide suitable shelter against moisture and temperature extremes if installed outdoors. Refer to appropriate drawing for mounting details.

Power Wiring

The Model 359A is to be powered from 110-130 volt only, 50 or 60 cycle a-c systems. The a-c supply voltage is connected to terminal L1 and L2 on the back of the instrument housing. All wiring should be in accordance with the applicable electrical codes. Where maximum protection of the instrument is desired, a 1/8 ampere fuse may be added in the power line to the instrument.

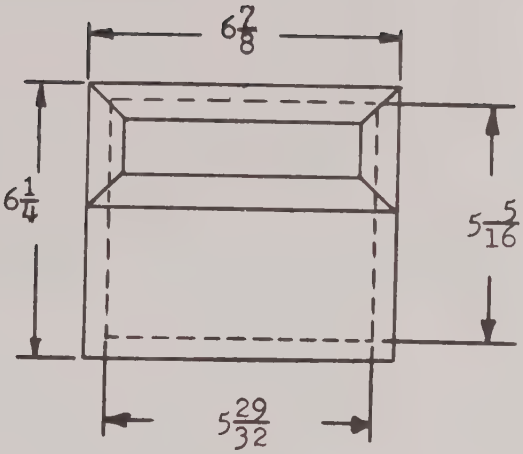
The instrument should be grounded. This is accomplished by attaching the ground terminal directly to a good ground, such as a cold water pipe.

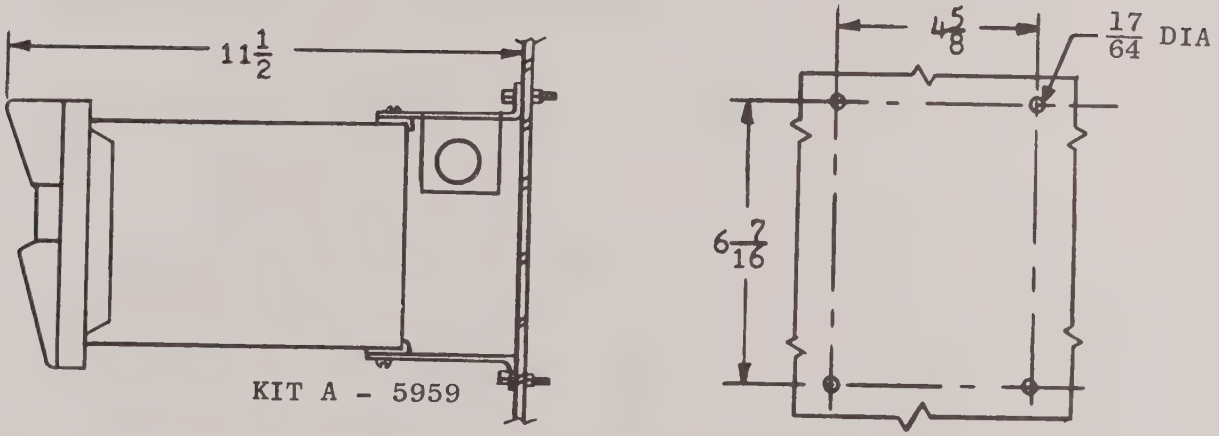
CAUTION:

Do not connect the GRD terminal to the neutral a-c line.

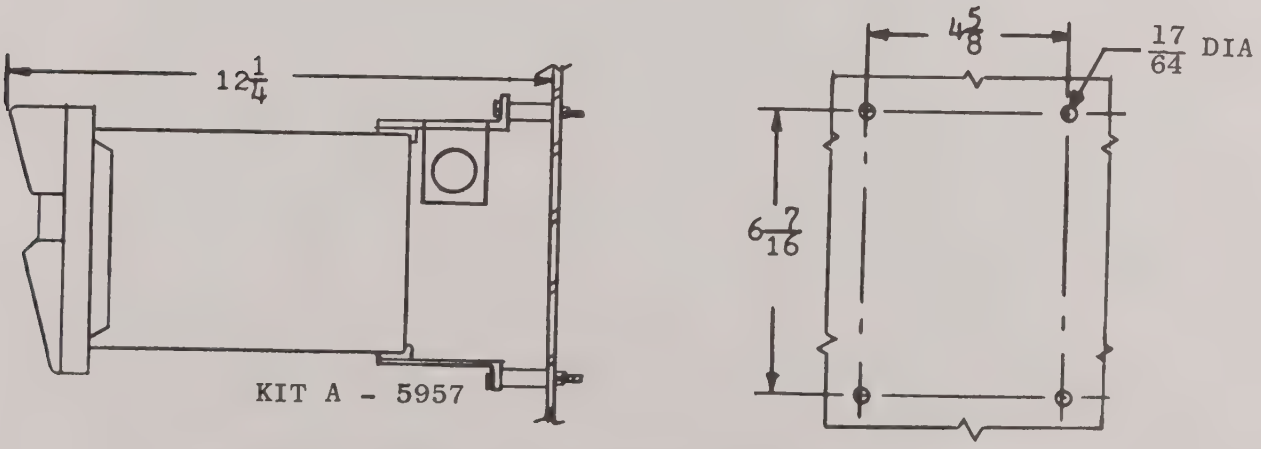
Terminals 5 and 6 are wired internally to the control chassis to obtain a d-c output voltage. Terminal 6 is the positive terminal, and terminal 5 is the negative terminal. The external wiring diagrams show some typical wiring diagrams.

FRONT VIEW AND
CASE DIMENSIONS



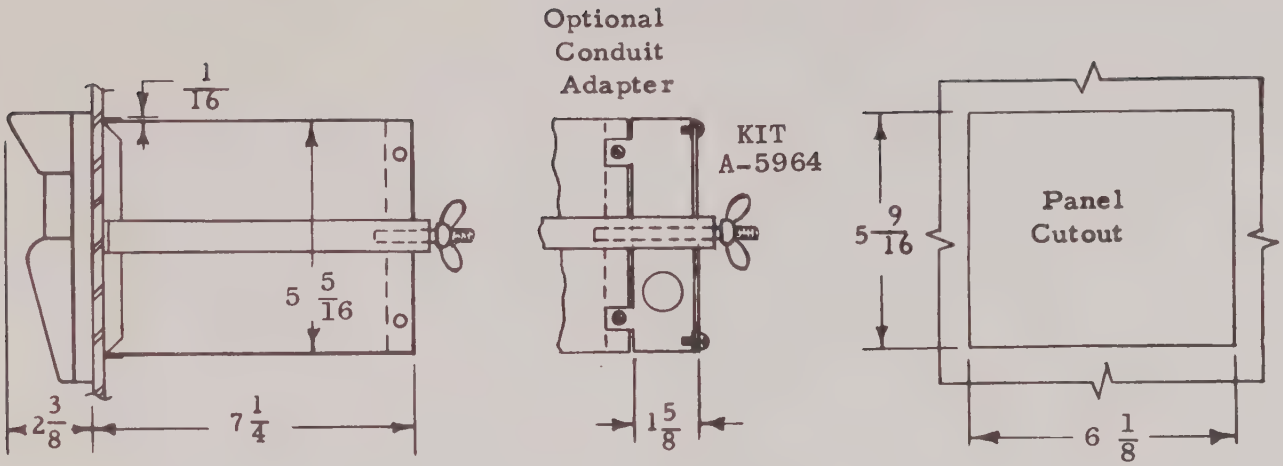


SURFACE MOUNTING DIMENSIONS

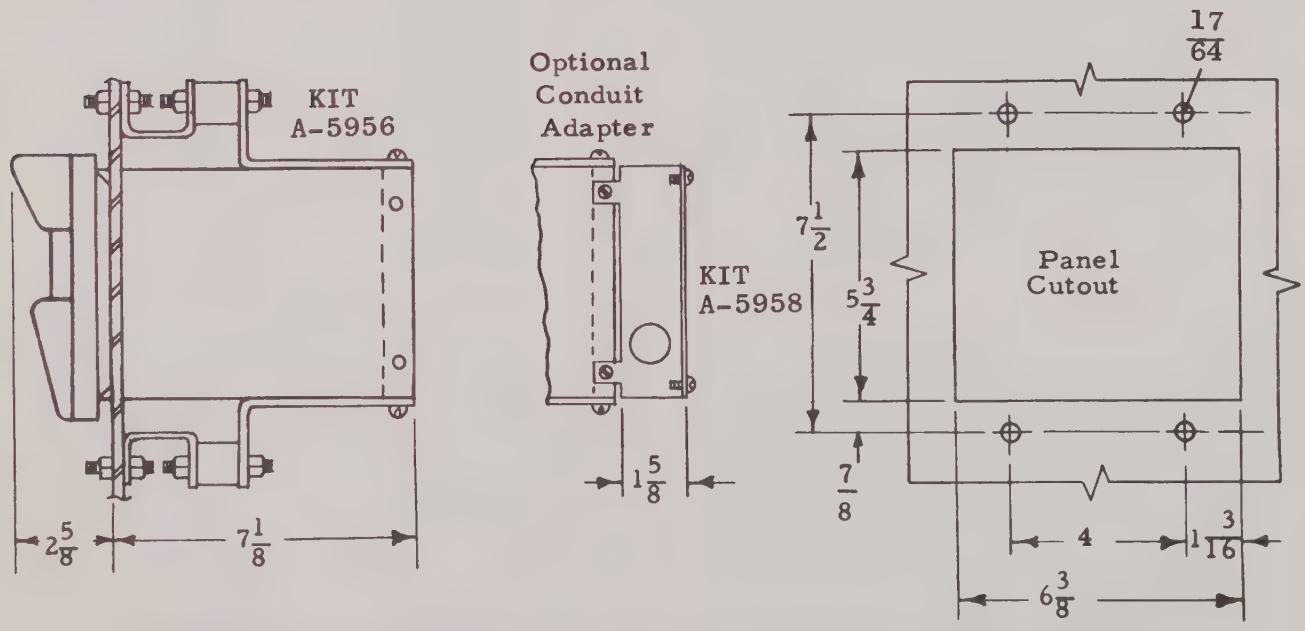


VIBRATION MOUNTING ARRANGEMENT FOR SURFACE MOUNTING

Figure 3



FLUSH MOUNTING DIMENSIONS



VIBRATION MOUNTING ARRANGEMENT FOR FLUSH MOUNTING

Figure 4

Meter Shunt Wire

After the instrument is installed, disconnect the jumper wire across terminals marked "Shunt", "TC-" and "TC+" on the back of the instrument. This wire is used to shunt or dampen the meter movement for protection during shipping, handling and installing the instrument, but should be removed for normal operation.

If the meter assembly is removed from the case, the automatic shunt device protects the meter assembly from damage. Shunt wiring is not required.

Thermocouple Wiring

Do not run thermocouple extension wire with other power or control wiring. Several thermocouple extension wires may be run in the same conduit, however.

Use only extension wire correct for the type of thermocouple (TC) as specified on the scale. The types most commonly specified are:

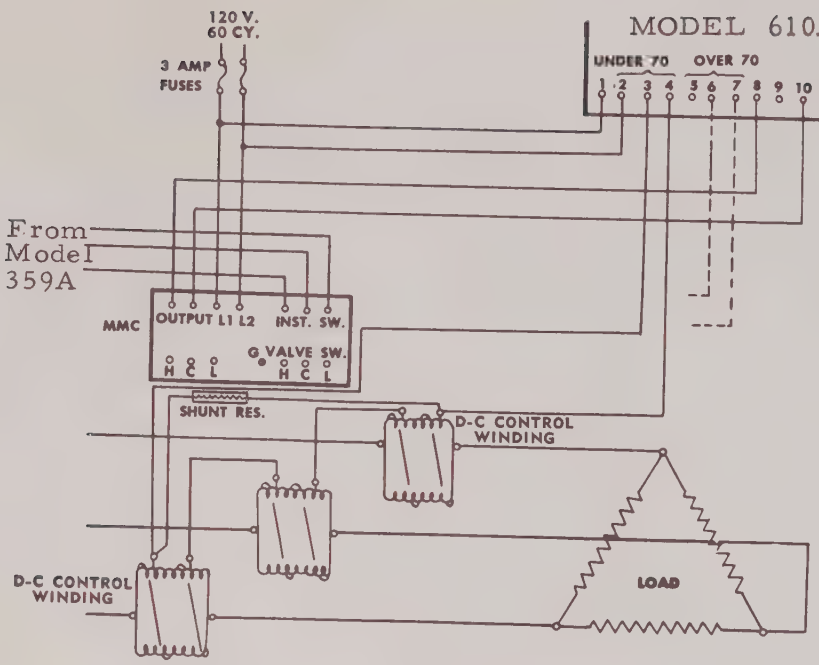
Iron-Constantan	Type J
Chromel-Alumel	Type K
Platinum-Platinum 10% Rhodium	Type S
Platinum-Platinum 13% Rhodium	Type R

Ordinary copper wire must not be used as extension wire. Consult your Barber-Colman field office for a selection of thermocouple assemblies and extension wire.

Thermocouple connections are made between the thermocouple head and TC terminals on the back of the instrument housing. Connect plus to plus and minus to minus, using the proper polarity and calibration of extension wire. Color coding red indicates the negative wire. If connections are made correctly, the indicating pointer will move to the right when the thermocouple hot junction is heated to a temperature higher than the equivalent setting of the digital set point. If it does not, set the reference voltage source to minimum voltage, disconnect the thermocouple, twist the ends of the extension wire together and heat this junction to a temperature sufficient to cause meter deflection. A left-to-right deflection of the indicator is proof of correct polarity of the extension wire, which means that the connections at the thermocouple head were reversed.

NOTE: The above means of checking polarity can apply only when the minimum range is zero or slightly over.

Secure the extension wires firmly under the terminal screws. Spade lugs may be used. If desired, the thermocouple output can be monitored by using the TC check terminals to the left under the front access cover.



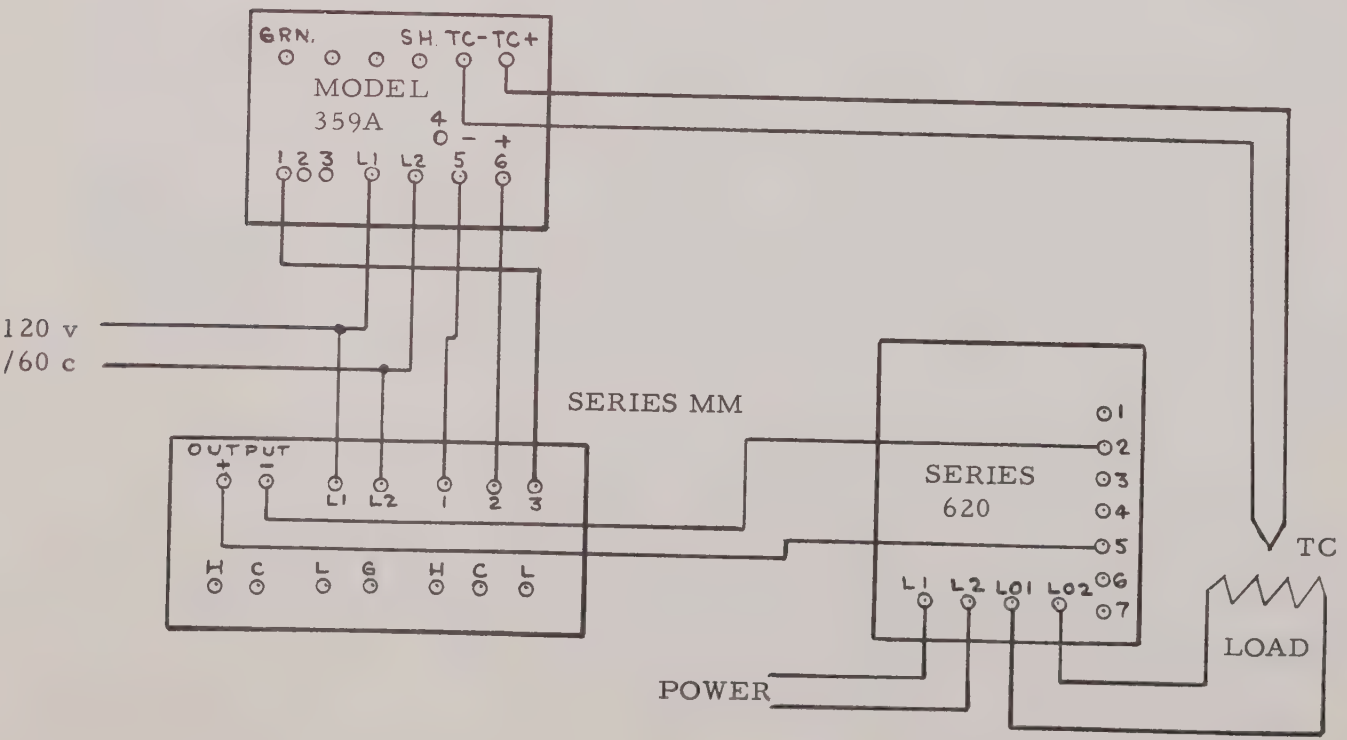
NOTE: (1) Use load term. 3 and 4 if resistance of reactor d-c control winding is between 30 and 70Ω. Use load term. 6 and 7 if resistance is between 70 and 150Ω.

NOTE: (2) Reactor d-c coils may be found to be parallel connected in special cases. Refer to mfgrs. spec. sheets accompanying reactor.

NOTE: (3) Identification of control winding terminals differ with various manufacturers.

Figure 5

External Wiring Diagram
Model 359A with MMC for Control of Three-Phase
Saturable Reactor (above) or Series 620 SCR Power Controller (below)



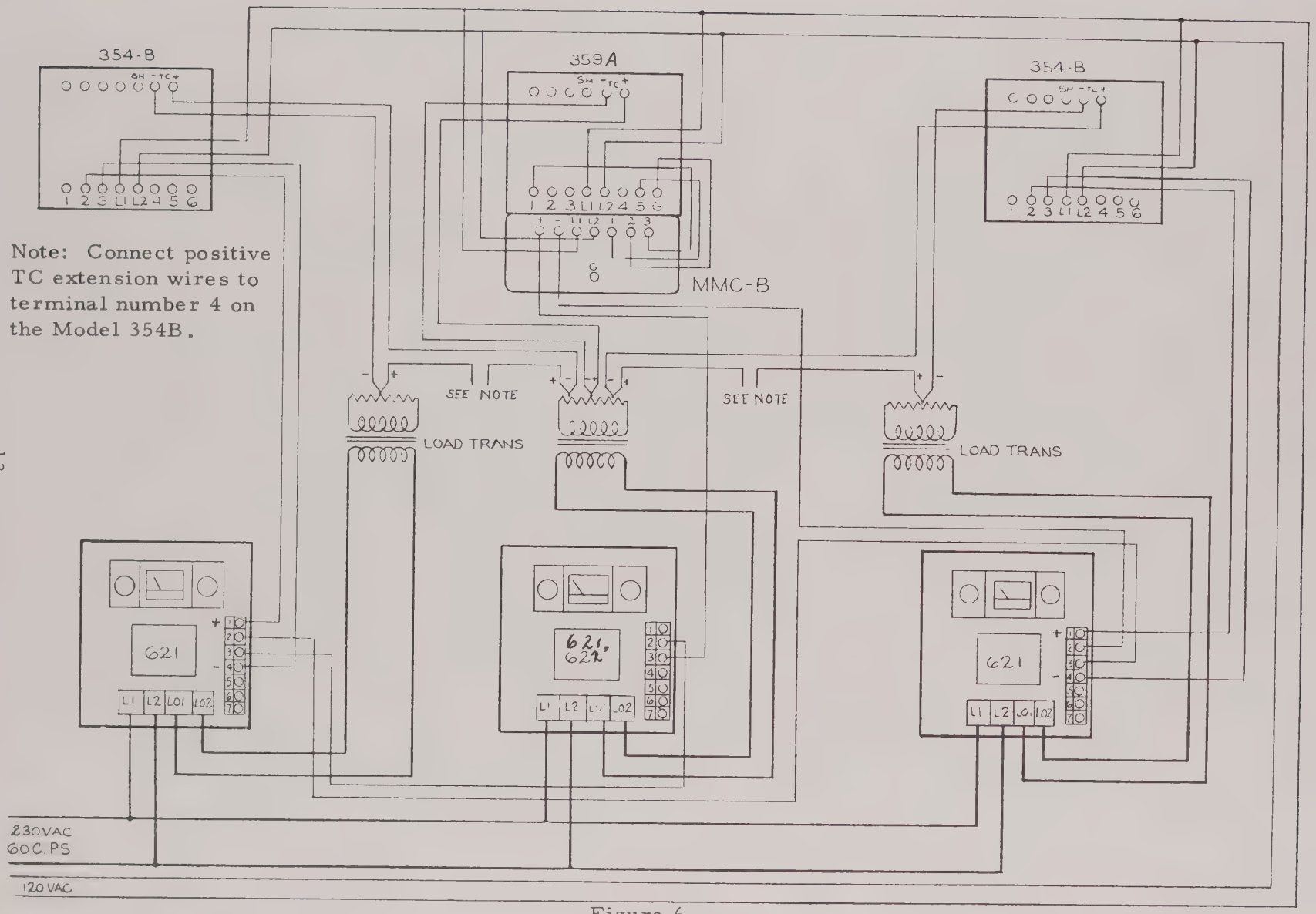


Figure 6

External Wiring Diagram of Locked Differential Systems for Three-Zone Control Using Model 621 Power Controller (center zone may use a Model 622)

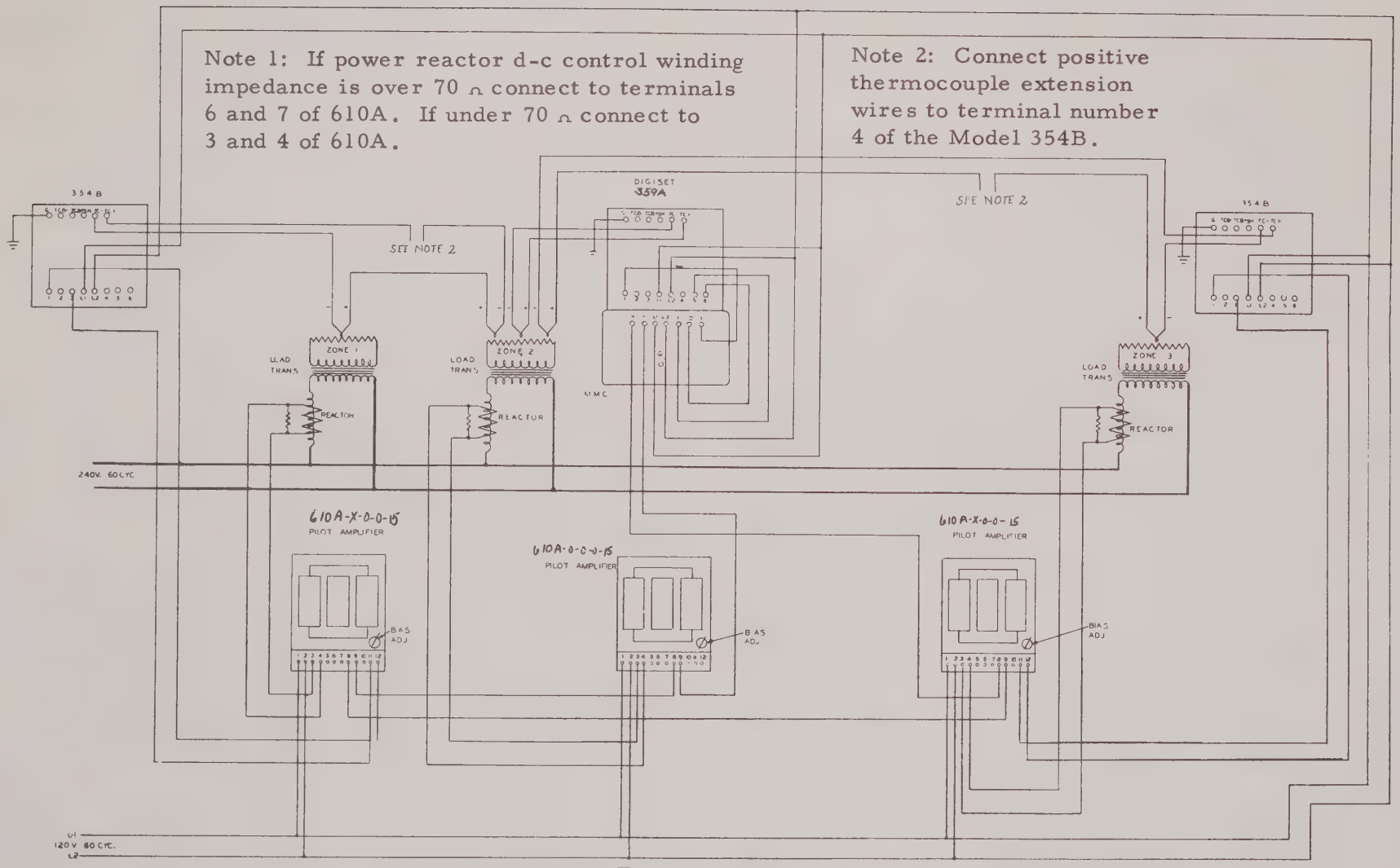


Figure
External Wiring Diagram of Locked Differential System for Three-Zone Control Using Pilot Amplifiers and Saturable Reactors

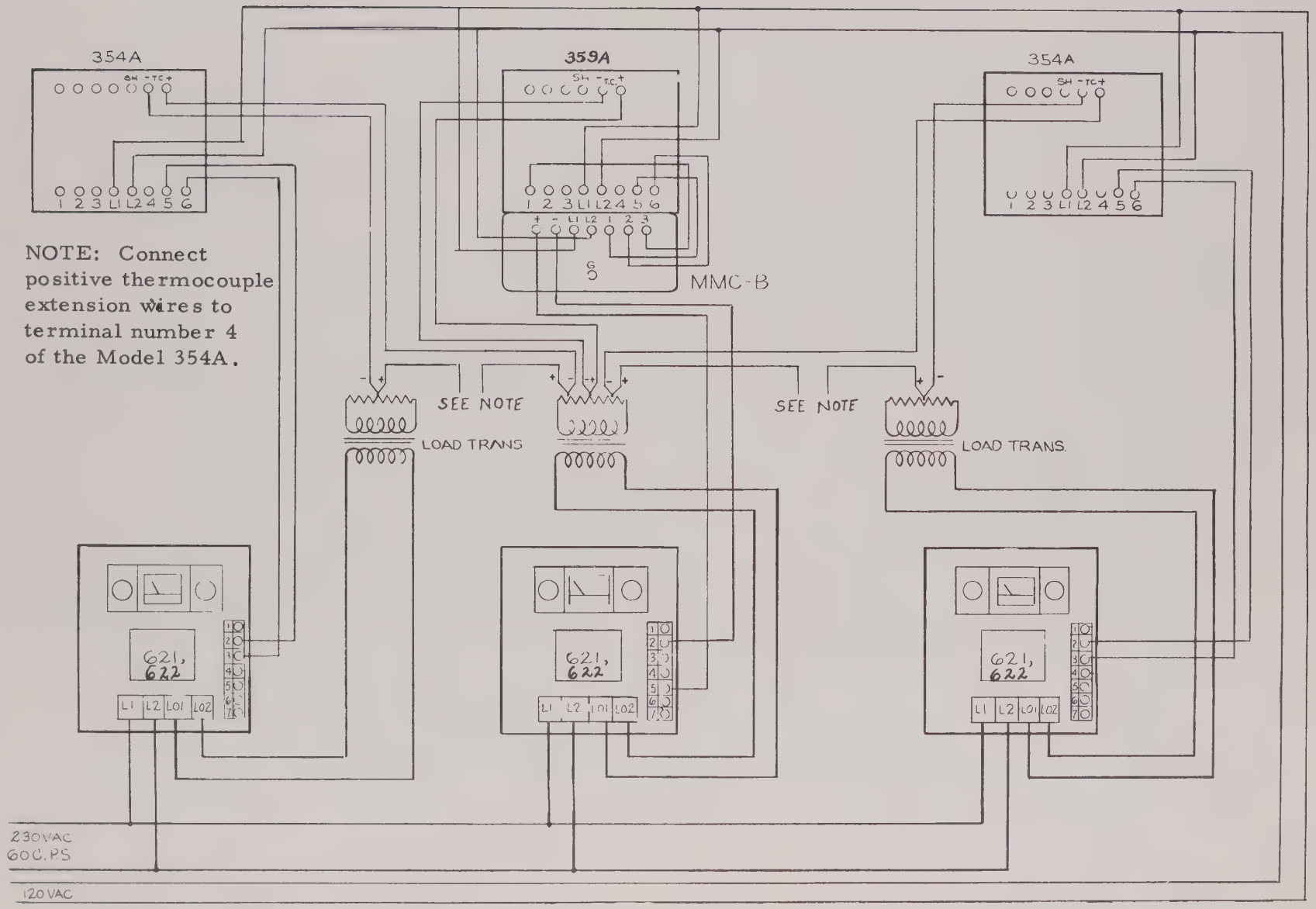


Figure 8
External Wiring Diagram of Master-Slave System for Three-Zone Control
Using Model 621 or 622 Power Controller

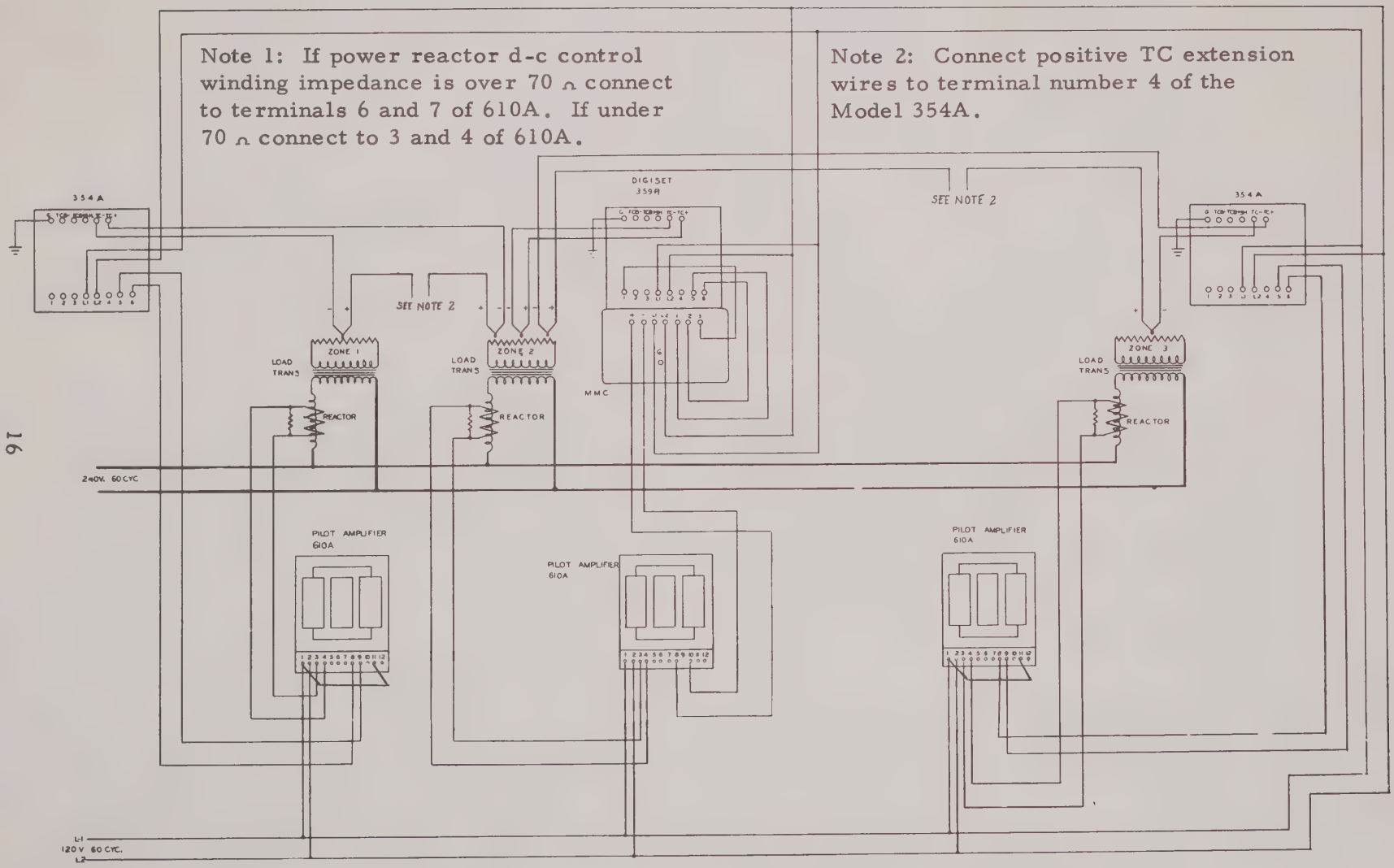


Figure 9

External Wiring Diagram of Master-Slave System for Three-Zone Control Using Pilot Amplifiers and Saturable Reactors

Cold Junction Compensation

For measuring temperature, thermocouples are the most commonly used sensing devices. They produce a voltage when there is a temperature difference between the "hot" or measuring junction and the "cold" junction located in the meter assembly. Since the difference in temperature between the hot and cold junctions determines the amount of millivoltage produced, it is necessary to keep the cold junction temperature constant, or to compensate for any changes that occur at this point. The Model 359A compensates for temperature changes at the cold junction electrically and automatically. Electrical cold junction compensation is accomplished by utilizing the resistance change, due to temperature, of a resistor. The resistance value would depend on the type of thermocouple used. Electrical cold junction compensation is furnished with most instruments, but may be omitted for special millivoltage measurement applications. See table of standard ranges listed in the back of this manual.

Thermocouple Circuit Resistance

Since the Model 359A utilizes a null balance arrangement in conjunction with a sensitive meter movement, the resistance of the thermocouple and leadwire has only a negligible effect on the controller. Such effect as it may have takes the form of altering slightly the response time or the sensitivity of the instrument. The greater the thermocouple measuring circuit resistance, the faster will be the meter response but with a decrease of sensitivity. In many applications, particularly with use of base metal thermocouples, additional resistance is added in series with the thermocouple input to increase the response of the meter (decreasing the response time) or to decrease the meter sensitivity. To add resistance to the measuring circuit, a 500 ohm potentiometer mounted inside the case on the back wiring panel may be adjusted to the desired additional resistance.* (Each graduation on the scale represents approximately 50 ohms). As shipped, the resistance potentiometer is set for zero resistance.

To obtain critical damping (the point at which the meter will reach control point in the least possible time without overshoot), 275 ohms resistance is added to the thermocouple measuring circuit. This is a setting of 5.5 on the potentiometer scale. The response time of the unit is thus reduced from 5.5 seconds to 1.4 seconds. As stated previously, the added resistance will decrease the sensitivity. This means that the microvolts required to cause the meter indicator to deflect one scale division is increased.

*Supplied only with instruments using base metal thermocouples.

The microvolts required to deflect the pointer one division can be determined from the nomograph (Figure 10). It is used in the following manner:

1. Determine the total thermocouple resistance of the meter. This is the combined resistance of the meter coil (95 ohms), thermocouple and extension wire, the potentiometer resistance inside the back panel and the reference voltage source (50 ohms). Total resistance can be figured by adding the value of each of these elements, or else by measuring the external resistance with an ohmmeter. To do this, remove the meter assembly and attach the ohmmeter leads to the TC connector springs, and then add the 95 ohms coil resistance and 50 ohms reference voltage source resistance to the value measured.

2. With the total resistance then known, draw a line from that resistance value through point A on the nomograph, intersecting the μv/division line, giving the microvolts per division.

3. If the degrees Fahrenheit or degrees Centigrade per division is desired, draw a line from the intersecting point on the μv/division line through point B, C or D, depending upon the thermocouple used, intersecting the °F or °C/division line, thereby giving the Fahrenheit or Centigrade degrees per per division.

The two examples shown neglect the thermocouple and extension wire resistances. One example is for a meter with coil resistance plus R.V.S. resistance, which is 145 ohms, and the other example applies to a unit that is critically damped (95 + 50 + 275 ohms). The sensitivity is shown to be 63.8 and 184.8 μv/division respectively. If a Pt/Pt 13% TC were used, this would result in 4.75°C/division for the coil plus R.V.S. resistance only and 13.5°C/division when the unit is critically damped.

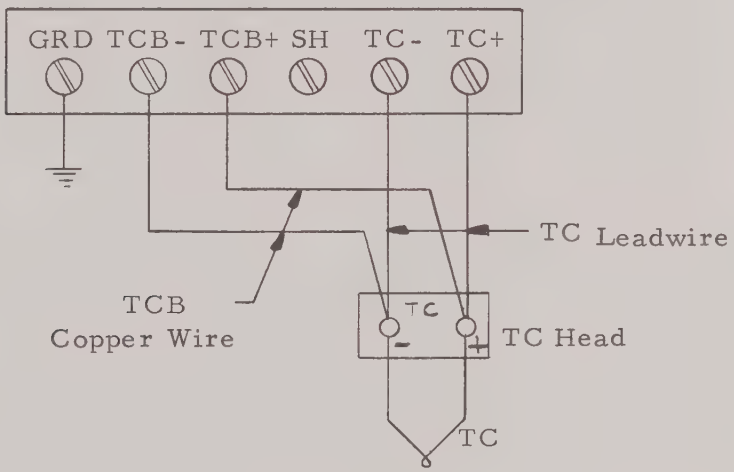
See section on "Proportional Control" for the effective proportional band.

Thermocouple Break Protection

The instrument is equipped with thermocouple break protection (TCB) to be used if desired. This protection is provided by utilizing a small d-c voltage that can be wired into the thermocouple circuit so that, in the event of an open thermocouple circuit, the meter indicator is driven to the right of the red arrows causing the output of the instrument to be decreased to its minimum value, thereby causing the output of the power controller to be at minimum power output.

The instrument will operate in a normal manner without TCB connected, but its usage may be desired on some applications to guard against overheating in the event of an open thermocouple.

The following diagram shows the connections necessary for TCB to be operative. Normally 16 to 20 gauge copper wire is used for the TCB connections. Wiring for TCB may be run in the same conduit with thermocouple wire.



To check for TCB operation, disconnect the thermocouple to simulate a broken thermocouple but leave the TCB wires connected. When the instrument is powered, TCB is functioning properly if the indicator is driven to the right of the red arrows causing the control output of the instrument to go to minimum.

When TCB is utilized a slight error is introduced into the measuring system. This can be checked and compensated for in the following manner: with the instrument powered, and with the thermocouple maintained at a steady temperature, disconnect one of the TCB lead-wires, set the automatic reset adjustment of the MM Series to zero, and notice if there is any slight meter indicator movement. If there is, note the scale position of the meter indicator and then reconnect the TCB lead. Next, adjust the screw on the top of the meter housing until the meter indicator is at the same position it was when TCB was disconnected. Compensation for TCB error has then been made.

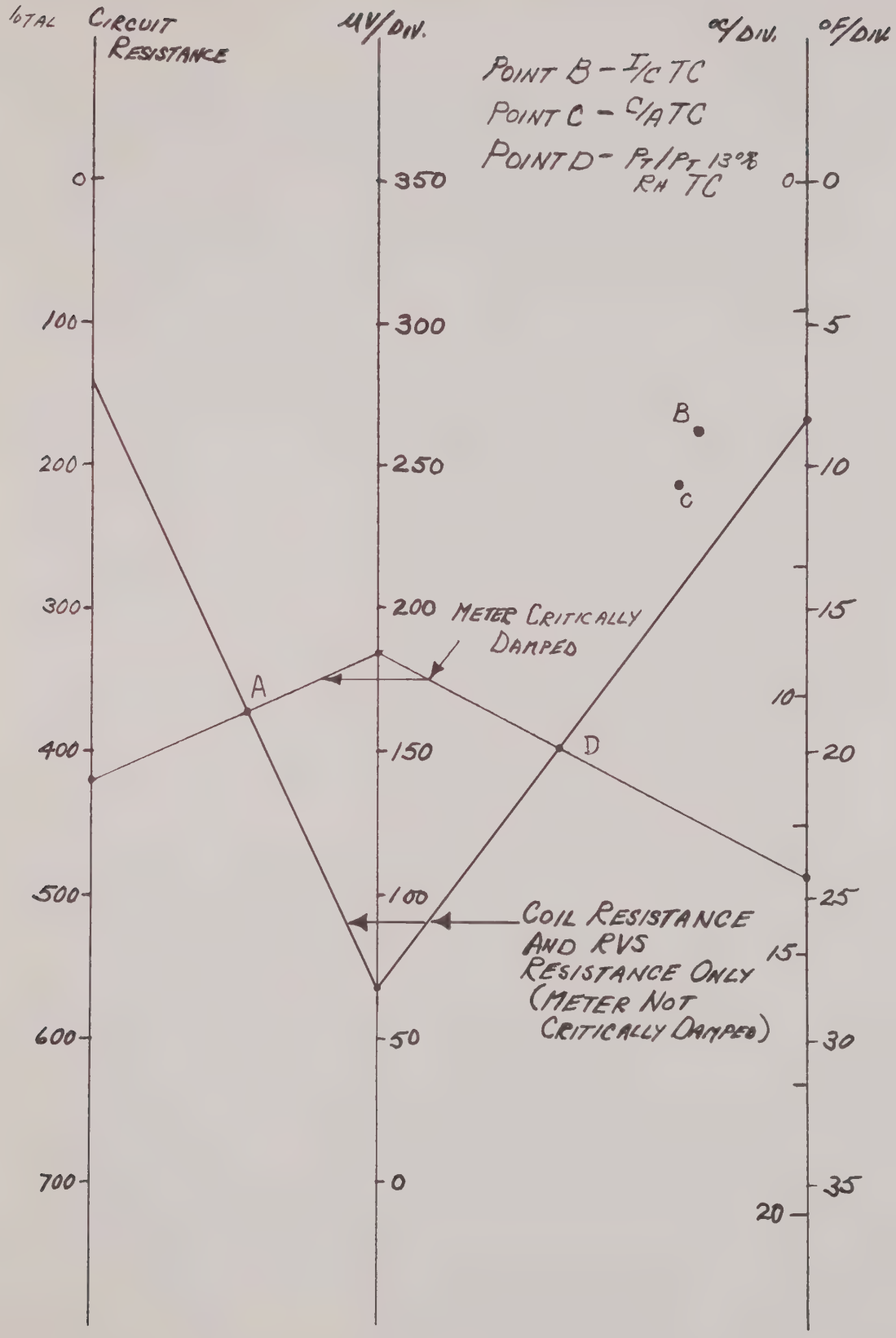


Figure 10
Nomograph of Meter Resistance vs Sensitivity

The meter indicator indicates the difference between a thermocouple input and the reference voltage source. When no difference exists the meter indicator coincides with the red arrows. The Model 359A has an instantaneous response because solid state devices operate without warm-up time. When the red signal light glows, the instrument is powered and the light will remain on until the power to the instrument is turned off. If a d-c voltmeter is connected across the test jacks, and with the output of the instrument connected to a controller, the voltmeter will show the output decreasing when the meter indicator moves from left to right, approaching the red arrows. This is the region where proportional control action occurs.

Set Point Adjustment

The control set point temperature or millivoltage is set and indicated by the three-digit dial to the left of the scale by the reference voltage source potentiometer. If the instrument is dual or triple range, the knob located below the scale must first be turned to the selected range. The red button on top of the meter is then depressed, releasing the dial lock on the set point knob, so the knob may be turned to the desired setting. After the temperature or millivoltage control point is set, the dial lock button is returned to its up position, holding the knob against accidental turning.

The temperature in degrees, or millivolts, per digit of the dial (units per digit) is obtained by dividing the selected range span by 1000. The digital equivalent of the set point value (degrees or millivolts) is then found by subtracting the lowest number of the selected range from the desired set point and then dividing by the units per digit. For example, if the range indicated is 500-1000°C and the desired set point temperature is 850°C, the dial would be set to read 700 thus:

$$1000 - 500 = 500 \text{ degree span}$$

$$\frac{500}{1000} = .5 \text{ degrees per digit}$$

$$\frac{850 - 500}{.5} = 700 \text{ dial setting}$$

If the instrument is calibrated in temperature, the reference voltage source output for a given set point may not be exact due to inherent non-linearity of thermocouple potentials. This is discussed in the first section under "Reference Voltage Source".

Control Adjustments

Final control adjustments should be made after the unit has been in operation 45 minutes and has obtained maximum stability. The chassis controls are accessible by removing the front access cover, which is easily removed by pulling the small knob located below the control set point knob.

The 359A is set up in the following manner:

1. Open the thermocouple circuit by disconnecting one thermocouple lead at the input terminals.

2. Using a screwdriver, carefully turn the alingment screw on top of the meter housing until the meter indicator is aligned with the red arrows.

3. Attach a d-c voltmeter to the control chassis output test terminals and read the output voltage.

4. With the meter indicator and the red arrows at coincidence the output voltage should be 6 volts d-c. If it is not 6 volts d-c, turn the reset adjustment on the front of the chassis until 6 volts d-c is obtained. (This is the point where the MM Controller meter should read 50%).

5. When an output of 6 volts d-c is obtained, no further adjustments are required since the MM unit has automatic reset in normal system operation.

6. Balance the MM Controller, following the procedure as outlined in the MM instruction book.

7. After the MM Series Controller has been properly balanced, circuit continuity can then be maintained by closing the thermocouple circuit which was previously opened.

After the control adjustments of the Model 359A are complete, adjustments may then be made for proportional band, rate and reset. These controls are on the MM unit, with procedure for adjusting described in the MM Series instruction manual.

Maintenance and Service Checks

The 359A instrument is well designed and manufactured of high grade components and with normal care will give uninterrupted service for a long time. It is good practice, however, to have information as to service and spare parts for emergency servicing. Where a number of instruments are located together, the plug-in parts are interchangeable to allow minimum inventory.

When trouble is encountered, the service man should familiarize himself with the process and instrument application to determine the exact function of the instrument as applied. The instrument trouble usually can be traced to two basic problems: measurement or control.

Measurement trouble can be detected by observing the pointer position. If the measurement is known to be in error, check the following:

1. Open or broken thermocouple, extension wire or connector.

2. Deteriorated thermocouple. Compare readings with a test thermocouple, or measure the thermocouple output using a potentiometer. The thermocouple input test terminals are located to the left just inside the access cover of the instrument.

3. Check to see that the capacitor is properly connected between the thermocouple input terminal and the ground terminal on the front side of the rear terminal board. Also ascertain that the instrument is properly grounded.

4. Accidental shorts, grounds, or moisture in the extension wire (especially with asbestos type insulation).

5. High resistance in leads due to loose connectors, poor splicing, dirty switch contacts, and other faulty connectors.

6. Problems caused by vibration or shock.

7. Errors due to oil or grease. Do not oil or grease any part of the instrument.

8. Incorrect alignment adjustment. The correctness of this setting should be checked following any meter servicing.

9. If the meter indicator does not coincide with the red arrows when the load is thermally stable, check for improper reset setting and balancing of the MM Series Controller as discussed under "Control Adjustments".

10. Improper thermocouple resistance (see page 17).

Control trouble may be detected by observing indicator pointer position with respect to the red arrows. If control action does not occur in the vicinity of the red arrows, do the following:

1. Check electrical connectors and correctness of line voltage. Ascertain as to whether trouble is internal or external to the instrument.

2. Determine if instrument, magnetic amplifier or power controller are powered; check load power for open circuits and open legs in three-phase circuits.

3. Check the supply voltage to the components. It should be within ± 10% of rated line voltage. Excessive line voltage variations can cause large fluctuations in load power.

4. If a saturable reactor is used, check to see if its rating is compatible with the load rating.

5. Check the output of the Model 359A by connecting a d-c voltmeter to the instrument's test terminals to measure the output. When the black indicator is well to the left of the red arrows, the meter reading should be greater than 11 volts d-c. When the black indicator is to the right of the red arrows, the test meter should read 1 volt d-c or less.

6. If the output meter of the MM unit shows less than 100% when the indicator is considerably to the left of the red arrows, check the MM Series proportional band setting.

7. If there is no power applied to the load with the instrument energized, attach a d-c voltmeter to the test jacks. If the voltmeter indicates zero output, make sure the meter indicator is well to the left of the red arrows and then turn the reset adjustment through its entire adjusting range. If the d-c voltmeter then indicates an output to the MM Controller, set the reset adjustment as described in the section on "Control Adjustments". If the instrument does not then function, further servicing or replacement of the control chassis is suggested.

8. Check the MM Controller. See the instruction book for the particular model of three-function controller used.

PARTS LIST

Item	Part No.	Description
C1	39-163	100 mfd + 80% -20% 50 v d-c w
D1	EYZP-384	Silicon Diode 80 piv 100 ma
D2	31-046	18 v ± 20% 1 watt Zener Diode
D3	31-027-100	9 - 9.8 v at 10 ma Temp. C. ± .005%/C°
R1	40-233	270 ohms ± 10% 1 watt Compensator
R2	40-160	530 ohms ± 1% 2.5 watt w.w.
R3	40-162	10 k ohms ± 1% 1 watt w.w.
R4	40-161	232 ohms ± 1% 2.5 watt w.w.
R5	40-180	1 k ohms ± 1% 3 watt w.w.
R6 thru R10		Calibrating Resistors (See Eng. Specs.)
R11	29-137	0-1000 ohms ± 3% 1.5 watt 10 turn pot
R12		1019.0 ohm ±.1% 3 watt
R14	SYZR-83-4	50 ohm Potentiometer
Rcj	A-3476	For Type J TC
	A-3477	For Type K TC
	A-3478	For Type T TC
	A-3479	For Type E TC
	A-3480	For Types R and S TC
S1	32-258	Rotary Switch

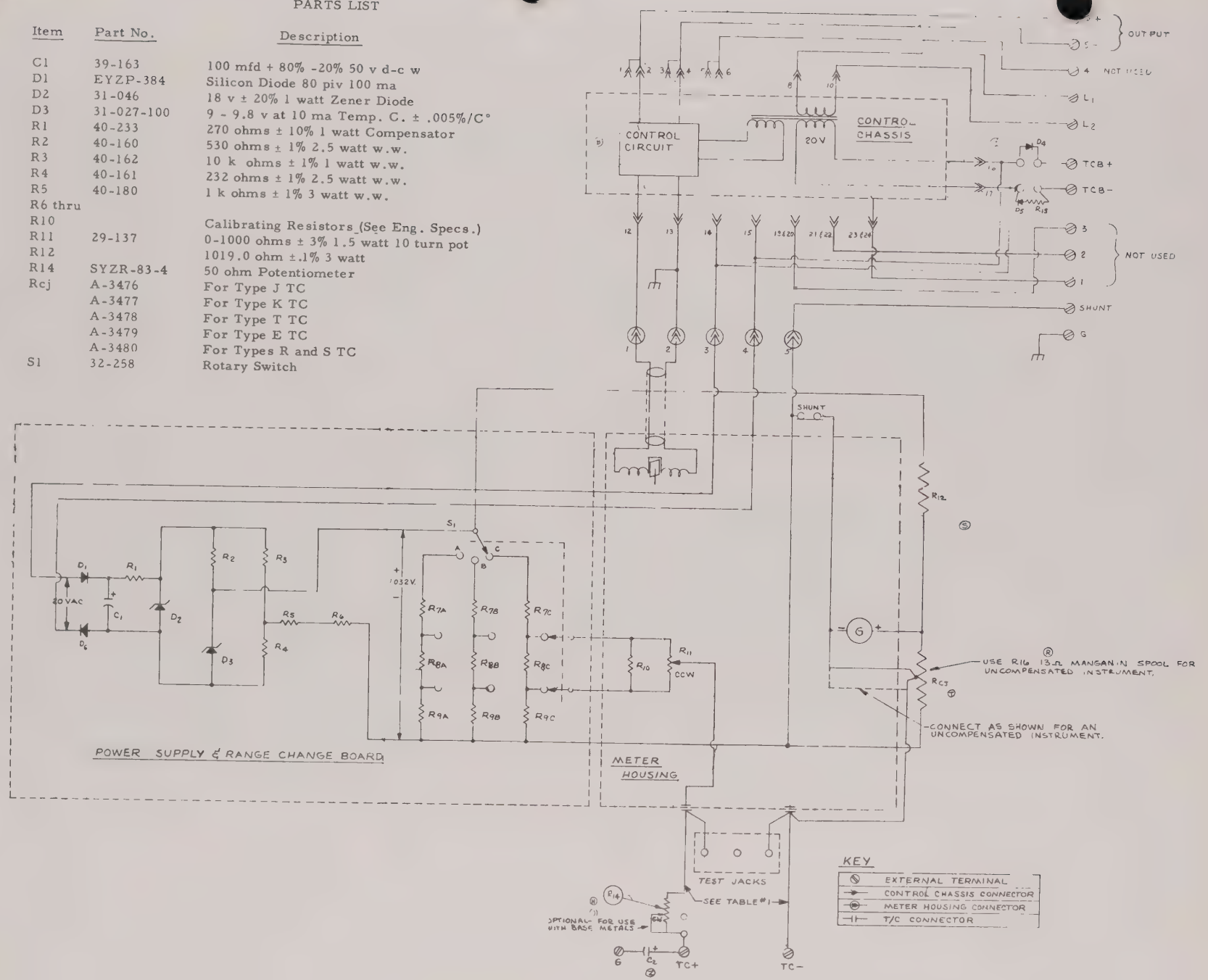


Figure 11
Model 359A Measuring Circuit Schematic

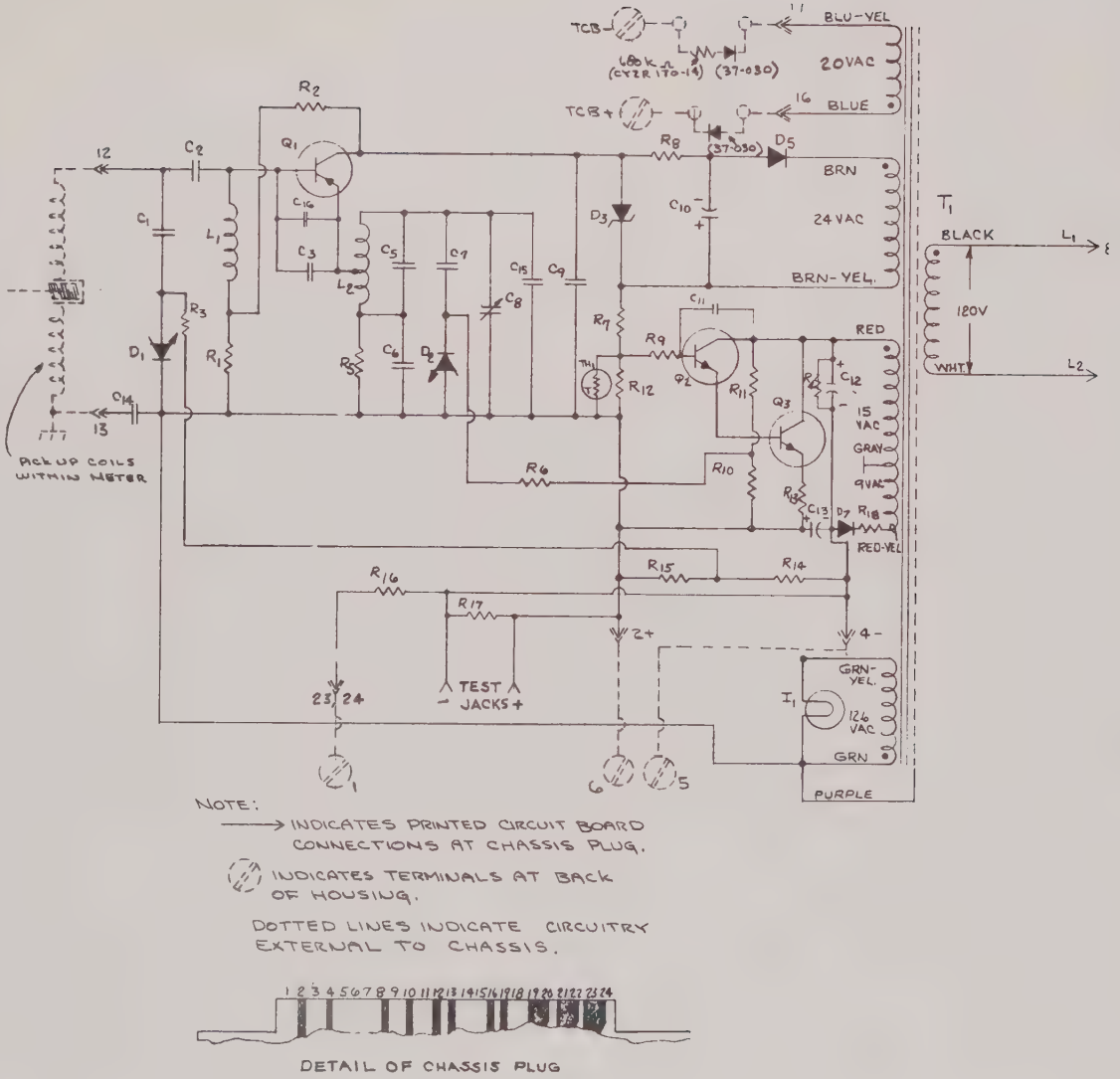


Figure 12
Model 359A
Control Circuit Schematic

PARTS LIST

For Parts Shown in Figure 12

Item	Part Number	Description
C1, C7	39-87	62 pf 500 v d-c w ± 5% NPO
C2, C6	39-203	270 pf 600 v d-c w ± 5% NPO
C3	39-212	8 pf 500 v d-c w ± 10% N4700
C5	39-80	47 pf ± 10% 600 v d-c w NPO
C8	39-160-1	2.9-35 pf
C9, C14	39-103	.01 mfd 1000 v d-c w GMV
C10	39-153	50 mfd 50 v d-c w -10 +150%
C11	39-228	.47 mfd 50 v d-c w ± 10%
C12, C13	39-163	100 mfd 50 v d-c w -20 +80%
C15	39-65	10 pf 500 v d-c w N1400
C16	39-155	10 pfd 600 v d-c w ± 5% NPO
D1, D2	37-60	Variable Capacitor 33 pf at -4 volts
D3	37-93	12 volt Zener Diode 400 mw ± 10%
D5, D7	EYZP 384	Silicon Diode 80 piv at 100 ma
I1	36-34	12.6 volt Bulb
L1	41-133	22 µH ± 10% Choke
L2	41-130-100	1.2 µH Coil
Q1	31-50	High Frequency Transistor (2N2188)
Q2, Q3	31-69	600 mw Silicon Transistor (2N696)
R1	CYZR 170-22	1000 ohm ± 10% 1/2 watt
R2	40-82	33 k ohm ± 10% 1/2 watt
R3	CYZR 170-18	4.7 megohms ± 10% 1/2 watt
R4	CYZR 170-58	10 k ohms ± 10% 1/2 watt
R5	40-77	270 ohms ± 10% 1/2 watt
R7	CYZR 170-47	330 ohms ± 10% 1/2 watt
R8	CYZR 133-2	1500 ohms ± 10% 1/2 watt
R9	CYZR 105	8200 ohms ± 10% 1/2 watt
R10, R15	CYZR 170-1	22 k ohms ± 10% 1/2 watt
R11, R14	40-70-2	47 k ohms ± 10% 1/2 watt
R12, R18	CYZR 170-28	220 ohms ± 10% 1/2 watt
R13	40-78	15 ohms ± 5% 1/2 watt
R16	CYZR 592-1	100 ohms ± 1% 3 watt w.w.
R17	CYZR 171-7	1000 ohms ± 10% 1 watt
T1	30-144	Power Transformer
TH1	CYZR 676	Thermistor

SUGGESTED REPLACEMENT PARTS TO KEEP ON HAND

Quantity	Part Number
2 MAZDA Pilot Lamps	36-34
1 Replacement Thermocouple	Barber-Colman can supply thermocouple assemblies, components or wire for any requirement you may have. If need be, delivery will be made in 48 hours. Contact your nearest Barber-Colman field office.
1 Indicating Meter Assembly	Specify range and calibration.
1 Control Chassis	A-6042

We do not recommend electronic component replacement except by well equipped instrument repair shops.

Barber-Colman, Industrial Instruments Division, maintains service and repair facilities in many major cities in the United States and Canada. Consult your yellow page directory.

MATERIAL WARRANTY

All equipment except tubes, photocells, and thermocouples, which within one year from date of shipment is found to have been originally defective, will be repaired (replaced if necessary) free of charge if returned prepaid to the Factory at Rockford, Illinois.

STANDARD RANGES AND THERMOCOUPLE ERRORS

On the following pages is a list of standard Digiset ranges, also showing the error to be expected for each temperature range due to thermocouple non-linearity. See Figure 1. The selection of range for a particular application must consider the measurement error acceptable. When close accuracy is required, it is recommended that a unit calibrated in millivolts with cold junction compensation be specified. The error due to thermocouple non-linearity would thus be eliminated.

The table below shows additional errors due to the standard limits of error of the thermocouple material. These errors, plus thermocouple non-linearity and instrument calibration errors, are additive (algebraically) for determining total maximum error possible for a given dial setting.

Calibration	Temperature Range	Standard Limits of Error
THERMOCOUPLE WIRE		
	-300 to - 75°F	- - -
Copper-Constantan	-150 to - 75°F	± 2%
Type T	- 75 to +200°F	± 1 1/2°F
	200 to 700°F	± 3/4%
Iron-Constantan	32 to 530°F	± 4°F
Type J	530 to 1400°F	± 3/4%
Chromel-Alumel	32 to 530°F	± 4°F
Type K	530 to 2300°F	± 3/4%
Platinum-Rhodium-Platinum	32 to 1000°F	± 5°F
Type R or S	1000 to 2700°F	± 0.5%

From I.S.A. Recommended Practice R.P. 1.3.

THERMOCOUPLE EXTENSION WIRE		
Copper-Constantan Type T	- 75 to 200°F	± 1 1/2°F
Iron-Constantan Type J	0 to 400°F	± 4°F
Chromel-Alumel Type K	0 to 400°F	± 4°F
Alternate Extension Wire Copper-Copper Alloy for use with Types R and S	75 to 400°F	± 12°F

NOTE: Percent limits of error shown are a percent of actual temperature indicated.

DIGISET STANDARD RANGES AND NON-LINEARITY ERRORS

NOTE:

(1) Ranges are listed in ascending order by top of range.

(2) Errors due to non-linearity of the thermocouple are figured at the midpoint of the temperature range. On either side of midpoint, error may be greater or less, depending on the shape of the thermocouple emf-temperature curves. See page 2.

Plus sign in front of the error figure designates the amount that actual temperature is above set point value. Minus sign designates actual temperature below set point.

IRON-CONSTANTAN Type J

Code Number	Ranges	Thermocouple Non-Linearity
306	0- 500 F	+3.5°
17	0-1000 F	+3.5°
2291	100- 600 F	+1.5°
	500-1000 F	+ .5°
2292	100- 600 F	+1.5°
	500-1000 F	+ .5
	900-1400 F	+5.0°
23	0- 500 C	+1.5°

CHROMEL-ALUMEL Type K

207	0-1000 F	+5.0°
2293	100-1100 F	+5.0°
	1000-2000 F	-7.5°
2296	100-1100 F	+5.0°
	1000-2000 F	-7.5°
	1900-2900 F	-5.0°
	(error for midpoint of 1900-2500 range)	
33	0-1000 C	0.0°
2295	100- 600 C	+4.0°
	500-1000 C	-3.0°
	900-1400 C	-5.5°

CHROMEL-ALUMEL (cont'd) Type K

Code Number	Ranges	Thermocouple Non-Linearity
2297	0-30 mv	
1373	0-50 mv	
1371	35-45 mv	
	43-53 mv	
2294	27-37 mv	
	36-46 mv	
	45-55 mv	
2324	0-20 mv	
	19-39 mv	
	38-58 mv	

COPPER-CONSTANTAN Type T

2309	-100 to + 400 F	+15.5°

13% PLATINUM-RHODIUM Type R

2302	100-1100 F	+28.0°
	1000-2000 F	+13.5°
	1900-2900 F	+ .5°
276	0-1000 C	+35.4°
1408	800-1300 C	+ 4.5°

13% PLATINUM-RHODIUM (cont'd)
Type R

Code Number	Ranges	Thermocouple Non-Linearity
2093	100- 600 C	+11.0°
	500-1000 C	+ 6.0°
	900-1400 C	+ 2.5°
1625	500-1000 C	+ 6.0°
	900-1400 C	+ 2.5°
1421	5-15 mv	
2299	0-10 mv	
	9-19 mv	
2301	0-10 mv	
	9-19 mv	
	18-28 mv	

10% PLATINUM-RHODIUM
Type S

2308	100-1100 F	+22.5°
	1000-2000 F	+11.0°
	1900-2900 F	0.0
106	0-1000 C	+28.3°
2304	800-1300 C	+ 3.5°
2307	100- 600 C	+ 8.0°
	500-1000 C	+ 5.0°
	900-1400 C	+ 2.0°
2305	0-10 mv	
	9-19 mv	
2306	0-10 mv	
	9-19 mv	
	18-28 mv	
1538	5-15 mv	

PLATINEL II
(Alloys 1813 and 1503)

Code Number	Ranges	Thermocouple Non-Linearity
2316	100-1100 F	+18.9°
	1000-2000 F	-13.5°
	1900-2900 F	-26.2°
	(midpoint error for range 1900-2732)	
2310	0-1000 C	+ 7.0°
1856	800-1300 C	- 8.6°
2315	100- 600 C	+ 6.0°
	500-1000 C	- 4.8°
	900-1400 C	-11.1°
2313	0-10 mv	
	9-19 mv	
	18-28 mv	
2312	35-45 mv	
	43-53 mv	
2314	27-37 mv	
	36-46 mv	
	45-55 mv	
2325	0-20 mv	
	19-39 mv	
	38-58 mv	

MV RANGES - UNCOMPENSATED

1438	0-10 mv
2320	0-10 mv
	9-19 mv
	18-28 mv
2317	0-30 mv
2318	0-50 mv
2321	0-10 mv
	0-25 mv
	0-50 mv
2319	0-25 mv
	0-50 mv

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